PATENT ABSTRACTS OF JAPAN

(11)Publication number : 06-053120
(43)Date of publication of application : 25.02.1994

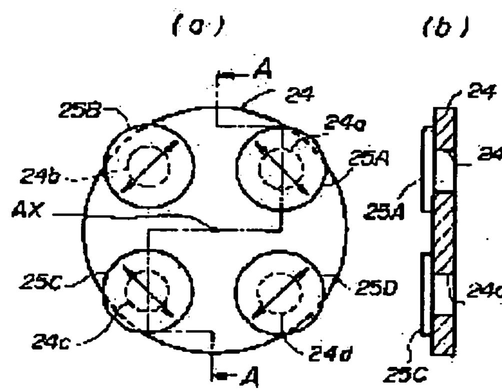
(51)Int.Cl. H01L 21/027
G03F 7/20

(21)Application number : 04-219782
(22)Date of filing : 27.07.1992

(71)Applicant : NIKON CORP
(72)Inventor : SHIBUYA MASATO

(54) ILLUMINATING OPTIC DEVICE

(57)Abstract:
PURPOSE: To improve image contrast for oblique illumination performed by a plurality of illuminating devices when a reticle pattern is a line-and-space pattern whose lengthwise direction is vertical to the incident plane of the illuminating light.
CONSTITUTION: Four apertures 24a-24d of a space filter as a secondary light source forming part are covered with a polarizing plates 24A-25D and the polarizing direction of the polarizing plates 25A-25D is set in the direction of the tangential line of a circumference whose axis is an optical axis AX.



LEGAL STATUS

[Date of request for examination]	26.07.1999
[Date of sending the examiner's decision of rejection]	
[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]	
[Date of final disposal for application]	
[Patent number]	3246615
[Date of registration]	02.11.2001
[Number of appeal against examiner's decision of rejection]	
[Date of requesting appeal against examiner's decision of rejection]	
[Date of extinction of right]	

CLAIMS

[Claim(s)]
[Claim 1] In the illumination-light study equipment which illuminates the predetermined field on a body to homogeneity by the illumination light from an illumination-light study system said illumination-light study system Illumination-light study equipment characterized by having a polarization means to form the illumination light which carries out the linearly polarized light in the inclination light means forming which forms the inclination light which illuminates said predetermined field from across, and the direction which intersected perpendicularly to the plane of incidence of said inclination light which changes this inclination light and carries out oblique illumination of said predetermined field.
[Claim 2] In the illumination-light study equipment which has the light source which supplies the illumination light, and the condensing optical system which illuminates the predetermined field on a body to homogeneity by this illumination light Arrange the inclination light means forming which forms the secondary light source which carried out eccentricity to the optical axis of said condensing optical system by said illumination light, and illuminates said predetermined field from across between said light sources and said condensing optical system, and this inclination light is changed. Illumination-light study equipment characterized by having arranged a polarization means to form the illumination light which carries out the linearly polarized light in the direction which intersected perpendicularly to the plane of incidence of the inclination light which carries out oblique illumination of said predetermined field, between said inclination light means forming and said condensing optical system.

[Translation done.]

* NOTICES *

JPO and NCIPI are not responsible for any damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention is applied to the illumination system of the projection aligner used in case a semiconductor device or a liquid crystal display component is manufactured, and relates to suitable illumination-light study equipment.
[0002]
[Description of the Prior Art] In case a semiconductor device or a liquid crystal display component is manufactured using a photolithography technique, the projection aligner which imprints a photo mask or the pattern of a reticle (it is hereafter named a "reticle" generically) on a sensitization substrate is used. In this projection aligner, to be able to burn a more detailed pattern with high resolution is demanded with high integration of a semiconductor device etc. The phase shift reticle method for using the cross protection of the light from the area pellucida from which the pattern space of a reticle differs as an approach of realizing this is indicated by JP,62-50811,B. If this approach is applied to Rhine - and - tooth-space image, the zero-order diffracted light will be lost fundamentally, and it becomes the image formation only by the primary [**] diffracted light, and Rhine - more detailed than the case of the conventional reticle and - tooth-space image can be burned in high resolution also by the projection optics of the same numerical aperture.
[0003] Moreover, as another approach for raising resolution more, an illumination-light study system is devised and the approach which is high resolution and can be burned with the comparatively deep depth of focus in a detailed pattern is proposed by these people (for example, collection of March, 1992 applied physics relation union lecture meeting drafts 30-a-NA -3, 4 reference). Below, the approach is explained per the approach with reference to "two or more oblique illumination method", a call, and drawing 8 . First, drawing 8 (a) shows the equivalence light source sections 10, such as the secondary light source sections in the illumination-light study system which applied two or more oblique illumination method, and the four small light sources 11A-11D are arranged in accordance with the symmetrical shaft in this drawing 8 (a) about shaft x' which crosses at 45 degrees to the x axis and the y-axis which form a rectangular coordinate system, respectively and this shaft x', and the y-axis. In the case of Rhine - and - tooth-space pattern with which the pattern of the reticle made applicable to an imprint has a long edge mainly parallel to a x axis, or a long edge parallel to the y-axis, the array of these small light sources 11A-11D is suitable.
[0004] Drawing 8 (b) shows the outline configuration of the projection aligner which makes the light source the equivalence light source section 10 of that drawing 8 (a), and is aslant irradiated by the reticle 12 to an optical axis AX in this drawing 8 (b) through the condenser-lens system in which chief ray 15A of the illumination light from small light source 11A of the equivalence light source section 10 carried out the illustration abbreviation. The equivalence light source sections 10 are pupil surface (entrance pupil side) 10A of projection optics 13, and conjugation, and aperture-diaphragm 13a is prepared in this pupil surface. From the reticle 12, zero-order diffracted-light (this is also expressed with sign 15A) and primary diffracted-light 16A is mostly injected by the symmetry to an optical axis AX, and these zero-order diffracted-light 15A and primary diffracted-light 16A carry out incidence of the **** for projection optics 13 to the wafer 14 as a sensitization substrate by the almost same incident angle theta. In this case, in order that zero-order diffracted-light 15A and the primary diffracted light may receive optical-axis AX and may pass near the periphery of a pupil to the symmetry, the resolution to the performance limit of projection optics 13 is obtained.
[0005] Moreover, by the method in which the zero-order diffracted light carries out incidence at right angles to a wafer 14 like before, since the wave aberration of the zero-order diffracted light to the amount of defocusing of a wafer 14 differs from the wave aberration of other diffracted lights greatly, the depth of

focus is shallow. On the other hand, with the configuration of drawing 8 (b), in order that the zero-order diffracted light and the primary diffracted light may carry out incidence to a wafer 14 by the equal incident angle, the depth of focus on which a phase etc. spreads the wave aberration of the zero-order diffracted light in case a wafer 14 is before and behind the focal location of projection optics 13, and the primary diffracted light is deep.

[0006]

[Problem(s) to be Solved by the Invention] It is effective if it is Rhine [of the direction of a x axis, or the direction of the y-axis] -, and - tooth-space pattern 8 by the two or more oblique illumination method. As shown in drawing 9 , a long edge receives a x axis or the y-axis. On the other hand, in the case of Rhine [of a 45-degree direction] -, and - tooth-space pattern 9 Supposing 10A is the pupil of projection optics, the diffracted light from small 2 [11B and 11D] of the four small light sources 11A-11D of drawing 8 (a) Only the zero-order diffracted lights 15B and 15D pass pupil 10A of a projection lens, and in order that the primary [**] diffracted lights 16B and 16D may not pass pupil 10A, they will not form a pattern on a wafer 14 and will only illuminate a wafer 14 uniformly. Consequently, the contrast of the pattern on a wafer 14 will fall.

[0007] Easy numerical calculation shows this. The strength of the primary [**] diffracted light to the strength of the zero-order diffracted light is set to a, and it is considered that each smallness light sources 11A-11D are the point light sources. At this time, Rhine - long in the direction of the y-axis and image intensity-distribution [on the x axis in the case of - tooth-space pattern] I (x) are as follows as the sum of the image intensity distribution by each smallness light source.

[Equation 1]

I(x) =4{1+a2+2 a-cos[(4 pi/lambda) (sintheta) x]}

[0008] Here, the incident angle theta is an angle which the zero-order diffracted light or the primary [**] diffracted light makes with an optical axis AX, as shown in drawing 8 (b). On the other hand, when x' shafts are set as the axis of coordinates of the direction of 45 degree in the case of Rhine - and - tooth-space pattern long in the direction which intersects a x axis or the y-axis at 45 degrees, intensity distribution I (x') are as follows.

[Equation 2]

I(x') = 2 {1+a2+2 a-cos [(4 pi/lambda) (sintheta) x]}
+2{1}
= 4 {1+(a2 / 2)+a-cos [(4 pi/lambda) (sintheta) x]}

[0009] (Several 1) It is as follows when it asks for the contrast Cx of each intensity distribution, and Cx' from reaching (several 2).

[Equation 3]

Cx=2a/(1+a2), Cx'=a/(1+a2/2)

[0010] In this case, a degree type is materialized.
Cx-Cx'=a/{(1+a2) (1+a2 / 2)}> 0, therefore a degree type are materialized.

[Equation 4] Cx>Cx' [0011] Therefore, the fall of the contrast of a long pattern is shown in the direction which intersects a x axis at 45 degrees. For example, since a is set to2/pi in the strength of the primary [**] diffracted light when the width of face of Rhine and a tooth space is equal, it becomes like a degree type. Cx=0.906, Cx'=0.529[0012] In addition, although above-mentioned explanation explained the case of two or more oblique illumination method as an example, even when zona-orbicularis illumination etc. is used, for example, to improve the contrast of an image more is desired. In the illumination-light study equipment which illuminates a reticle etc., using positively the illumination light toward which this invention inclined to the optical axis in view of this point When patterns, such as the reticle, are Rhine - and - tooth-space patterns which make a longitudinal direction a direction perpendicular to the plane of incidence of the illumination light When patterns, such as the reticle, are projected by projection optics, it aims at enabling it to improve the contrast of the image with the device by the side of illumination-light study equipment.

[0013]

[Means for Solving the Problem] In the illumination-light study equipment to which the 1st illumination-light study equipment by this invention illuminates the predetermined field on a body (12) to homogeneity by the illumination light from an illumination-light study system as shown in drawing 3 The inclination light means forming which forms the inclination light (27B, 27C) in which the illumination-light study system illuminates the predetermined field from across (24), This inclination light is changed and it has a polarization means (25B, 25C) to form the illumination light which carries out the linearly polarized light in the direction which intersected perpendicularly to the plane of incidence of that inclination light that carries

out oblique illumination of that predetermined field.
[0014] Moreover, the 2nd illumination-light study equipment is set to the illumination-light study equipment which has the light source (20) which supplies the illumination light, and the condensing optical system (26) which illuminates the predetermined field on a body (12) to homogeneity by this illumination light, as shown in drawing 3 . The inclination light means forming (24) which forms the secondary light source which carried out eccentricity to the optical axis of the condensing optical system by the illumination light, and illuminates the predetermined field from across is arranged between the light source (20) and its condensing optical system (26). This inclination light is changed and a polarization means (25B, 25C) to form the illumination light which carries out the linearly polarized light in the direction which intersected perpendicularly to the plane of incidence of the inclination light which carries out oblique illumination of that predetermined field is arranged between that inclination light means forming (24) and its condensing optical system (26).
[0015]
[Function] Hereafter, the illumination light from the four small light sources which carried out eccentricity per principle of this invention explains taking the case of two or more oblique illumination method which illuminates a body. First, according to the 1st illumination-light study equipment of this invention, as shown, for example in drawing 3 , the inclination light (27B, 27C) which illuminates an objective (12) predetermined field from across is formed, and the linearly polarized light (an electric vector vibrates in the direction perpendicular to plane of incidence) of these inclination light (27B, 27C) is carried out in the direction perpendicular to the plane of incidence (space) to a body (12), respectively. In addition, the linearly polarized light means the condition that the oscillating direction of the electric vector of a light wave is in 1 flat surface, and the oscillating direction of an electric vector is defined as the direction of the linearly polarized light. Moreover, with plane of incidence, when light arrives at the interface of a medium, it is defined as the thing of a field including the normal of the field in the point, and the direction of incidence of light. If the illumination-light study equipment of the drawing 3 is simplified, it will become like drawing 1 .
[0016] Drawing 1 (a) shows the equivalence light source sections 10, such as the secondary light source sections of the illumination-light study equipment of drawing 3 , and the four small light sources 11A-11D are arranged in accordance with the symmetrical shaft in this drawing 1 (a) about shaft x' which crosses at 45 degrees to the x axis and the y-axis which form a rectangular coordinate system, respectively and this shaft x', and the y-axis.
[0017] Drawing 1 (b) shows the outline configuration of the projection aligner which used the illumination-light study equipment of that drawing 3 , and its equivalence light source section 10 is equal to the equivalence light source section of drawing 1 (a) in this drawing 1 (b). Chief ray 15A of the exposure light from small light source 11A of the equivalence light source section 10 is aslant irradiated by the reticle 12 to an optical axis AX through the condenser-lens system which carried out the illustration abbreviation. The chief ray 15A corresponds to the inclination light (27B, 27C) of drawing 3 . Since the plane of incidence of the chief ray 15A is parallel to the space of drawing 1 (b), according to this invention, the linearly polarized light (an electric vector vibrates in the direction perpendicular to space) of the chief ray 15A is carried out in the direction perpendicular to the space of drawing 1 (b), and it carries out incidence to a reticle 12. Similarly, in drawing 1 (a), the linearly polarized light of the light from each smallness light sources 11B-11D is carried out in the direction, i.e., the direction perpendicular to the plane of incidence to a reticle 12, of the arrow head of drawing 1 (a), and it carries out incidence to the reticle 12 of drawing 1 (b).
[0018] Moreover, incidence of the zero-order diffracted light (this is also expressed with sign 15A) from a reticle 12 and the primary diffracted-light 16A is carried out on a wafer 14 through projection optics 13. First, supposing the patterns formed in the reticle 12 are Rhine - long in a direction parallel to the x axis or the y-axis of drawing 1 (a) which is a suitable pattern for the conventional example, and - tooth-space pattern, since the polarization direction is the direction of 45 degree to the pattern, the illumination light diffracted in x directions or the direction of y with the pattern is in the same image formation situation as random polarization. Therefore, contrast is the same as the conventional example.
[0019] On the other hand, supposing the patterns formed in the reticle 12 are Rhine - long in a direction perpendicular to x' shafts of drawing 1 (a), and - tooth-space pattern 9, the primary diffracted light of illumination-light 15A from small light source 11A will enter in the pupil of projection optics 13. In addition, in drawing 1 (b), x' shafts are space and parallel. Here, as shown in drawing 1 (b), zero-order diffracted-light 15A and primary diffracted-light 15B of the illumination-light 15A are S polarization (light to which an electric vector vibrates in the direction perpendicular to the space of drawing 1 (b)) with both

the polarization directions (direction where an electric vector vibrates) parallel on the front face of a wafer 14. Therefore, it becomes larger than the time of the cross protection on a wafer 14 being random polarization, and the image of high contrast is made. For this reason, when it diffracts in the direction of x', and a part of diffracted light comes out of a pupil, conventional un-arranging [that contrast falls] will be compensated [as explained using drawing 9 ,].

[0020] Here, the difference of the intensity distribution by the polarization direction is described below briefly. Drawing 2 has shown the situation the image surface, i.e., near the front face of a wafer 14, using P polarization (light which has the oscillating direction of an electric vector in plane of incidence), and S polarization (light with the oscillating direction of an electric vector perpendicular to plane of incidence). It is the incident angle of zero-order diffracted-light 15A and primary diffracted-light 16A, respectively theta 0 And theta 1 When it carries out, the intensity distribution Is on the image surface in S polarization (x) are briefly shown as follows using amplitude distribution Us (x).

[Equation 5]

Is(x) =|Us(x) |2 Vs(x) =a0 and exp [-i(2 pi/lambda) (sintheta0) x]
+ a1 and exp [-i(2 pi/lambda) (sintheta 1) x]

[0021] Therefore, intensity distribution Is (x) are as follows.

[Equation 6]

Is(x) =a02+a12+2a0 a1 and cos [(2 pi/lambda) (sintheta0-sintheta1) x]

Here, it is a multiplier a0. And a1 It is the (amplitude) in the strength of the zero-order diffracted light and the primary diffracted light, respectively. In the case of Rhine - and - tooth-space pattern which have a pitch in the direction of x', since, as for two, only the zero-order diffracted light passes projection optics 13 among the four small light sources, the contrast Cs of S polarization is as follows.

[Equation 7] Cs=2a0a1/(2a02+a12)

[0022] On the other hand, in P polarization, x components and z component of polarization must be considered. A degree type will be obtained, if the amplitude distribution Up on the image surface in P polarization (x) is expressed with a vector and x components and z component are shown.

[Equation 8]

Up (x) = () [a0, exp [-i(2 pi/lambda) (sin theta0) x], and] [cos theta0] + a1 and exp [-i(2 pi/lambda) (sin theta1) x] and cos theta1, a0 and exp [-i(2 pi/lambda) (sin theta0) x] and sin theta0 +a1 and exp [-i(2 pi/lambda) (sin theta1) x] and sin theta1

[0023] Therefore, the intensity distribution Ip on the image surface in P polarization (x) are as follows.

[Equation 9]

Ip(x) =|Up(x) |2 =a02+a12+2a0 a1 x (costheta0 costheta1+sintheta0 sintheta1)
xcos[(2 pi/lambda) (sintheta0-sintheta1) x]

[0024] Therefore, the contrast Cp in P polarization is as follows.

[Equation 10]

Cp=2a0 a1 cos(theta0-theta1)/(2a02+a12)

(Several 7) (several 10) is compared and, in P polarization, it turns out that contrast becomes cos (theta0-theta1) twice. For example, considering the case of sintheta0 =0.4 and sintheta1 =-0.4, it is set to cos(theta0-theta1) =0.68 and, the case of P polarization, and in the case of S polarization, a big difference sticks. Since random polarization is considered to be an average with P polarization and S polarization, contrast is =(1 (1/2)+0.68) 0.84.

[0025] Thus, a big difference arises in contrast by considering as S polarization. That is, when the illumination light of a polarization condition like drawing 1 (a) is used, the increment in the contrast of about twenty percent is conventionally expected to Rhine - with an parallel edge, and - tooth-space pattern in the direction which crosses at 45 degrees to a x axis and the y-axis, and it turns out that it is effective in a detailed pattern.

[0026] In addition, what is necessary is just to change into the light which carries out the linearly polarized light of the light from the light source of the shape of zona orbicularis of the equivalence light source section 10 to a direction respectively perpendicular to plane of incidence, i.e., the tangential direction of the circle centering on an optical axis, as shown, for example in drawing 7 (a) if this invention is applied to for example, zona-orbicularis illumination although explained until now taking the case of two or more oblique illumination method.

[0027] Next, according to the 2nd illumination-light study equipment of this invention, as shown, for example in drawing 3 , the secondary light source which carried out eccentricity by the illumination light from the light source although inclination light is formed is formed. If it considers that the secondary light

source is the equivalence light source 10 of drawing 1 (a), above-mentioned explanation will be applied also to this invention as it is.
[0028]
[Example] Hereafter, with reference to drawing 3 and drawing 4 , it explains per 1st example of the projection aligner equipped with the illumination-light study equipment by this invention. This example applies this invention to the illumination-light study system of a projection aligner. The illumination-light study system of the projection aligner of this example is shown, the illumination light from the light source 20 which consists of a mercury lamp is condensed in the ellipse mirror 21 in this drawing 3 , and this condensed illumination light carries out incidence of drawing 3 to the fly eye lens 23 (optical integrator) through a collimator lens 22. Field-like the secondary light source is formed in the focal plane by the side of injection of the fly eye lens 23 (reticle side).
[0029] The spatial filter 24 with which four openings which carried out eccentricity to the optical axis AX were formed near the injection edge of the fly eye lens 23 is formed. Moreover, polarizing plates 25A-25D are put on the reticle side (or it may be a light source 20 side) of four openings of this spatial filter 24, respectively. However, in drawing 3 , only polarizing plates 25B and 25C have appeared. As drawing 4 (a) is a sectional view which meets AA line of drawing 4 (a) and shows the front view which looked at the spatial filter 24 of drawing 3 from the reticle side, and drawing 4 (b) to these drawing 4 (a) and (b), four openings 24a-24d are formed in a spatial filter 24 at intervals of 90 degrees centering on an optical axis AX, and these openings are covered with polarizing plates 25A-25D, respectively. Moreover, the polarization direction of these polarizing plates 25A-25D is set as the tangential direction of the periphery centering on an optical axis AX, respectively, as an arrow head shows. Therefore, the linearly polarized light of the illumination light injected from the openings 24a-24d of the spatial filter 24 is carried out in the direction respectively almost parallel to the tangential direction of the periphery centering on an optical axis AX.
[0030] The four secondary light sources which carried out eccentricity to drawing 3 to the optical axis AX with return and a spatial filter 24 are formed. After the illumination light injected from these four secondary light sources passes polarizing plates 25A-25D, respectively, incidence of it is carried out to a reticle 12 through the condenser-lens system 26. In addition, the spatial filter 24 (polarizing plates 25A-25D) is formed in the before [the condenser-lens system 26] side focal (light source side focus) location, and the pattern formation side of a reticle 12 has the arrangement side of a spatial filter 24, and the relation of the Fourier transform about the condenser-lens system 26. Incidence of the chief rays 27B and 27C injected from the openings 24b and 24c of a spatial filter 24 in this case is aslant carried out to an optical axis AX through the condenser-lens system 26 on a reticle 12, respectively. Moreover, the linearly polarized light of these chief rays 27B and 27C is carried out in the perpendicular direction to the plane of incidence (the direction of space) to a reticle 12, respectively.
[0031] When Rhine - which has a long edge, and - tooth-space pattern are formed in the parallel or perpendicular direction to the straight line which connects the openings 24a and 24c of drawing 4 (a) on a reticle 12 as principle explanation of this invention explained for example, if such an illumination-light study system is used, the pattern can be projected on a wafer 14 through projection optics 13 under good contrast rather than before. Here, the incidence side face and body side (the reticle 12 or wafer 14) of the fly eye lens 23 are constituted by conjugate, and the injection side face (secondary light source 10) of the fly eye lens 23 and pupil surface 10A of projection optics 13 are constituted from equipment of drawing 3 by conjugate. in addition, another big polarizing plate between [other than the configuration of drawing 3] the fly eye lens 23 and a spatial filter 24 -- arranging -- a part of four openings 24a-24d of a spatial filter 24 -- or -- all -- alike -- 1/2 wavelength plate -- arranging -- every -- you may make it adjust the angle of rotation of 1/2 wavelength plate The illumination light which polarized also by this to the tangential direction of the periphery centering on the optical axis AX as shown in drawing 4 (a) is obtained. In this case, therefore, it is necessary to form ** and 1/2 wavelength plate in the polarization direction of another big polarizing plate at no openings of a spatial filter 24.
[0032] furthermore -- for example, -- the case where the whole spatial filter 24 of drawing 3 which serves as the equivalence light source by using the laser light source by which the laser beam of the linearly polarized light is injected as the light source is illuminated by the illumination light of the linearly polarized light -- a part of four openings 24a-24d of a spatial filter 24 -- or what is necessary is just to boil all and to form 1/2 wavelength plate of a suitable hand of cut In this case, although it is also good for a part of openings to form 1/2 wavelength plate, it is effective when the way which forms 1/2 wavelength plate in all openings reduces the variation in lighting. Thus, when the polarization direction is adjusted using 1/2 wavelength plate, since there is no loss of the illumination light, lighting effectiveness is good.

[0033] Moreover, when illuminating the spatial filter 24 of drawing 3 used as the equivalence light source using the equipment which generates the illumination light of the circular polarization of light as a whole, it is good to form the quarter-wave length plate of the suitable hand of cut for each opening of a spatial filter 24.
[0034] Next, with reference to drawing 5 , it explains per 2nd example of this invention. Drawing 5 shows the projection aligner of this example, and the illumination light from the light source 20 becomes the parallel flux of light mostly in this drawing 5 through the ellipse mirror 21, the bending mirror 28, and the input lens 29. Supply of the illumination light to the input lens 29 is suspended at any time by bending with that ellipse mirror 21, arranging a shutter 30 between mirrors 28, and closing this shutter 30 with a drive motor 31. As the light source 1, the excimer laser which generates for example, KrF laser light etc. can be used out of a mercury lamp. When using an excimer laser, a beam expander etc. is used instead of the optical system to the ellipse mirror 21 - the input lens 29.
[0035] And the 2nd polyhedron prism 33 which has the heights of the 1st polyhedron prism 32 which has the crevice of 4 pyramid molds (pyramid mold), and 4 pyramid molds (pyramid mold) sequentially from the input lens 29 is arranged. The illumination light injected from this 2nd polyhedron prism 33 is divided into the four flux of lights with equiangular around the optical axis centering on the optical axis.
[0036] Incidence of the flux of light divided into these four pieces is carried out to the fly eye lenses 34A, 34B, 34C, and 34D of the 2nd group, respectively. Although only the fly eye lenses 34A and 34B are shown by drawing 5 , on both sides of the optical axis, two fly eye lenses 34C and 34D are arranged in the direction perpendicular to the space of drawing 5 . And the flux of light injected from fly eye lens 34A is mostly changed into the parallel flux of light through the guide optical system which consists of lens systems 35A and 36A, and carries out incidence to fly eye lens 37A of the 1st group. Similarly the flux of light which injected fly eye lens 34B of the 2nd group It is mostly changed into the parallel flux of light through the guide optical system which consists of lens systems 35B and 36B, and incidence is carried out to fly eye lens 37B of the 1st group. Incidence of ** which carries out an illustration abbreviation, and the flux of light which injected the fly eye lenses 34C and 34D of the 2nd group is carried out to the fly eye lenses 37C and 37D of the 1st group through guide optical system, respectively.
[0037] The fly eye lenses 37A-37D of the 1st group are arranged at intervals of 90 degrees around the optical axis. Although field-like the secondary light source is formed in the reticle side focal plane of the fly eye lenses 37A-37D of the 1st group, respectively, the adjustable aperture diaphragms 38A-38D are arranged to the forming face of these secondary light sources, respectively. Furthermore, polarizing plates 39A-39D are arranged, respectively to the reticle side of these adjustable aperture diaphragms 38A-38D. In addition, in drawing 5 , only the adjustable aperture diaphragms 13A and 13B and polarizing plates 39A and 39B have appeared.
[0038] It is moderately condensed through the auxiliary condenser lens 40, a mirror 41, and the main condenser lens 42, respectively, and the illumination light which penetrated and injected polarizing plates 39A-39D from these adjustable aperture diaphragms 38A-38D illuminates a reticle 12 with an almost uniform illuminance. The pattern of the reticle 12 is imprinted for the predetermined contraction scale factor beta according to projection optics 13 by the wafer 14 on the wafer stage WS. The polarization direction of these polarizing plates 39A-39D is parallel to the tangential direction of the periphery centering on an optical axis AX. For example, chief ray 43A of the flux of light penetrated and injected carries out incidence of adjustable aperture-diaphragm 38A to the polarizing plate 39A aslant to an optical axis AX on a reticle 12, where the linearly polarized light is carried out in the direction perpendicular to space. In addition, the polarizing plates 39A-39D shown in drawing 5 are substantially formed in the before [the condenser-lens system of the synthetic system of the auxiliary condenser lens 40 and the main condenser lens] side focal (light source side focus) location, and this location is pupil surface 10A of projection optics 13, and conjugation substantially.
[0039] The contrast of the projection image on Rhine [of the predetermined direction of / on a reticle 12] - and the wafer 14 of - tooth-space pattern is improvable with this example. Furthermore, since the fly eye lenses 34A-34D of the 2nd group other than the fly eye lenses 37A-37D of the 1st group are formed, the homogeneity of the illuminance on a reticle 12 is improved further. In addition, in drawing 5 , polarizing plates 39A and 39B may be arranged, for example in the locations 44A and 44B between relay optical system, respectively, and may be arranged in the location of further others. Moreover, when the illumination light from the light source 20 is already the linearly polarized light, 1/2 wavelength plate may be used instead of polarizing plates 39A and 39B.
[0040] Next, with reference to drawing 6 and drawing 7 , it explains per 3rd example of this invention. This

example changes the spatial filter 24 of the 1st example shown in drawing 3 explained previously, and shows the example which formed the spatial filter 240 which has opening 240a of the shape of **** zona orbicularis shown in drawing 6 (a) in the injection side of the fly eye lens 23. The secondary light source 45 of the shape of zona orbicularis which carried out eccentricity to the injection side of the fly eye lens 23 from the optical axis AX by arrangement of this spatial filter 240 as shown in drawing 6 (a) is formed, and the light from the secondary light source 45 of the shape of this zona orbicularis reaches pupil surface 10A (entrance pupil side) of projection optics 13 through a condenser lens 26 and a reticle 12, as shown in drawing 3 . Here, if the situation of the zero-order diffracted light and the primary diffracted light by Rhine [of a reticle 12] - and diffraction operation of - tooth-space pattern is considered in order to simplify explanation, as shown in drawing 6 (b), primary diffracted-light 45B of the shape of zona orbicularis to which the strike slip of zero-order diffracted-light 45A of the shape of zona orbicularis [**** / the zona-orbicularis light source 45] and the zona-orbicularis-like zero-order diffracted-light 45A was carried out will be formed in pupil surface 10A of this projection optics 13.

[0041] In this case, in this example, as shown in drawing 7 (a), the polarizing plate 250 of the shape of zona orbicularis which polarizes the illumination light injected from the secondary light source 45 of the shape of zona orbicularis of the equivalence light source section 10 to the tangential direction of the periphery centering on an optical axis AX, respectively is formed on the spatial filter 240. Thereby, the image of high contrast can be obtained to a detailed pattern. In addition, as shown in drawing 7 (b), polarizing plates 250A-250H are formed on each zone using the spatial filter 240 with opening which divides the zona-orbicularis-like light source into each radii-like zone, and you may make it become the illumination light of the linearly polarized light of the tangential direction of the periphery centering on an optical axis AX for every zone.

[0042] In addition, as for this invention, it is needless to say that configurations various in the range which is not limited to the above-mentioned example and does not deviate from the summary of this invention can be taken.

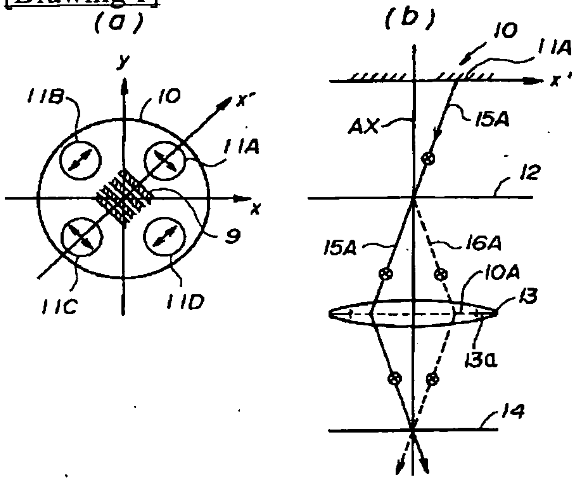
[0043]

[Effect of the Invention] According to the 1st [of this invention], and 2nd illumination-light study equipment, it inclines to a body, and when the pattern on the body is Rhine - and - tooth-space pattern which make a longitudinal direction a direction perpendicular to the plane of incidence of the illumination light, and the pattern of the body is projected by projection optics, there is [since the illumination light which carries out incidence is polarizing in the direction perpendicular to plane of incidence] an advantage which can improve the contrast of the image sharply.

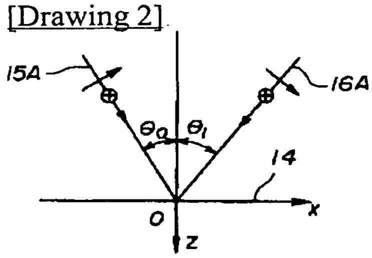
[Translation done.]

DRAWINGS

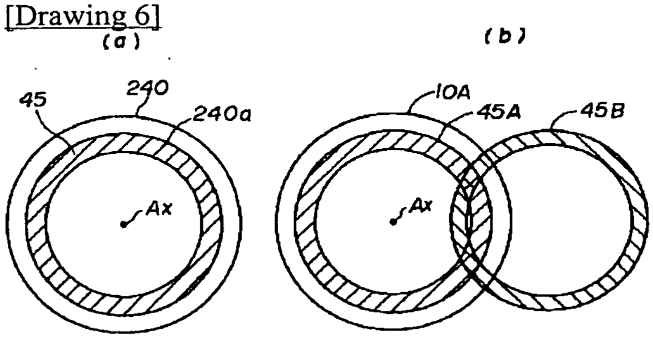
[Drawing 1]



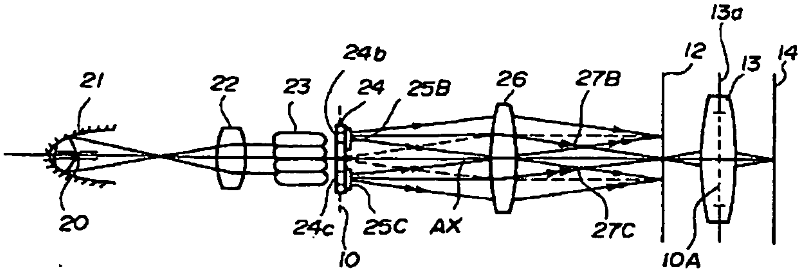
[Drawing 2]



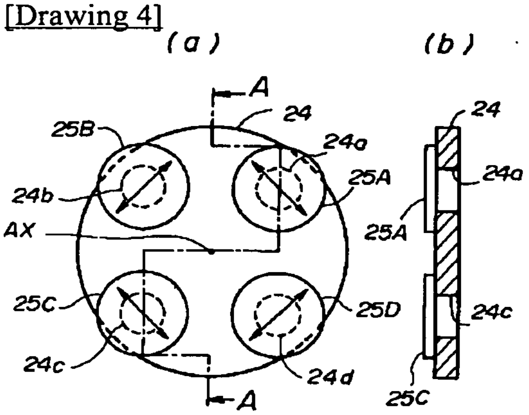
[Drawing 6]



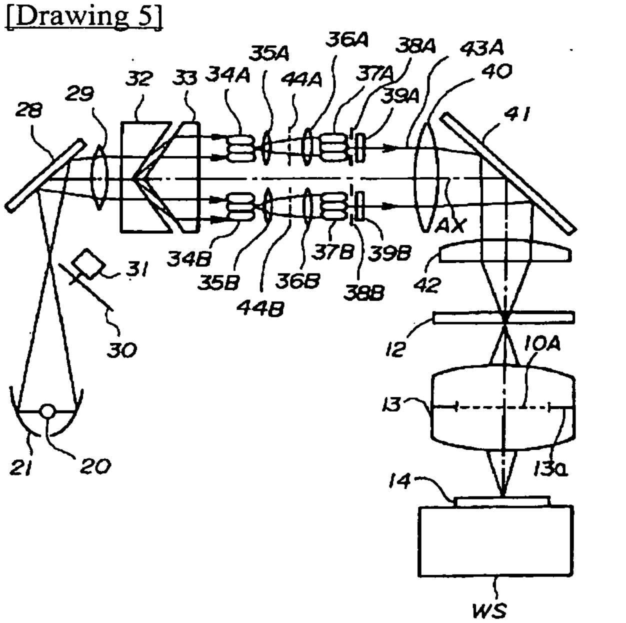
[Drawing 3]



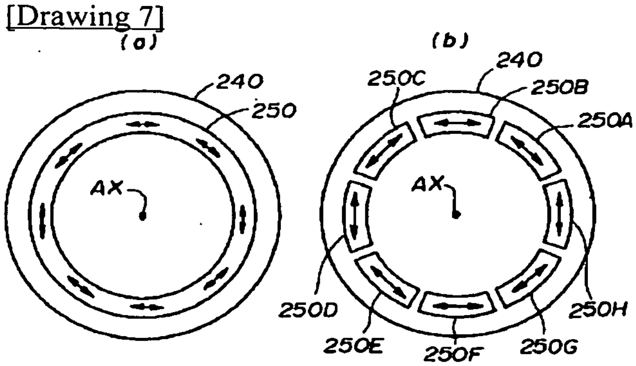
[Drawing 4]



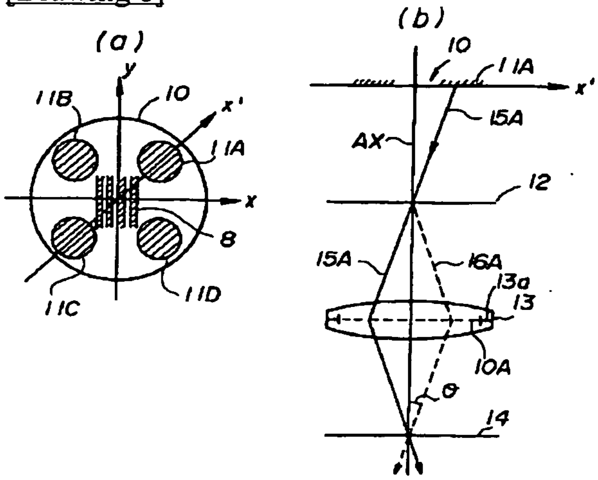
[Drawing 5]



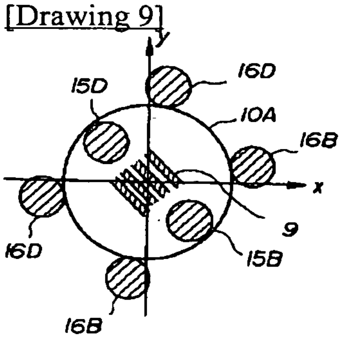
[Drawing 7]



[Drawing 8]



[Drawing 9]



[Translation done.]

CORRECTION OR AMENDMENT

[Kind of official gazette] Printing of amendment by the convention of 2 of Article 17 of Patent Law
[Section partition] The 2nd partition of the 7th section
[Publication date] March 16, Heisei 13 (2001. 3.16)

[Publication No.] JP,6-53120,A
[Date of Publication] February 25, Heisei 6 (1994. 2.25)
[Annual volume number] Open patent official report 6-532
[Application number] Japanese Patent Application No. 4-219782
[The 7th edition of International Patent Classification]

```
H01L  21/027
G03F   7/20    521
```

[FI]

```
H01L  21/30    311 S
G03F   7/20    521
```


[Procedure revision]
[Filing Date] December 21, Heisei 11 (1999. 12.21)
[Procedure amendment 1]
[Document to be Amended] Specification
[Item(s) to be Amended] The name of invention
[Method of Amendment] Modification
[Proposed Amendment]
[Title of the Invention] The exposure approach using illumination-light study equipment and this equipment
[Procedure amendment 2]
[Document to be Amended] Specification
[Item(s) to be Amended] Claim
[Method of Amendment] Modification
[Proposed Amendment]
[Claim(s)]
[Claim 1] In the illumination-light study equipment which illuminates the predetermined field on a body to homogeneity by the illumination light from an illumination-light study system,
Said illumination-light study system is illumination-light study equipment characterized by having a polarization means to form the illumination light which carries out the linearly polarized light in the inclination light means forming which forms the inclination light which illuminates said predetermined field from across, and the direction which intersected perpendicularly to the plane of incidence of said inclination light which changes this inclination light and carries out oblique illumination of said predetermined field.
[Claim 2] In the illumination-light study equipment which has the light source which supplies the illumination light, and the condensing optical system which illuminates the predetermined field on a body to homogeneity by this illumination light,
The inclination light means forming which forms the secondary light source which carried out eccentricity to the optical axis of said condensing optical system by said illumination light, and illuminates said predetermined field from across is arranged between said light sources and said condensing optical system,

Illumination-light study equipment characterized by having changed this inclination light and having arranged a polarization means to form the illumination light which carries out the linearly polarized light in the direction which intersected perpendicularly to the plane of incidence of the inclination light which carries out oblique illumination of said predetermined field, between said inclination light means forming and said condensing optical system.
[Claim 3] The exposure approach characterized by illuminating the reticle as said body using illumination-light study equipment according to claim 1 or 2, and imprinting the pattern of said reticle.
[Procedure amendment 3]
[Document to be Amended] Specification
[Item(s) to be Amended] 0012
[Method of Amendment] Modification
[Proposed Amendment]
[0012] In addition, although above-mentioned explanation explained the case of two or more oblique illumination method as an example, even when zona-orbicularis illumination etc. is used, for example, to improve the contrast of an image more is desired. In the exposure approach which uses the illumination-light study equipment and such illumination-light study equipment which illuminate a reticle etc., using positively the illumination light toward which this invention inclined to the optical axis in view of this point When patterns, such as the reticle, are Rhine - and - tooth-space patterns which make a longitudinal direction a direction perpendicular to the plane of incidence of the illumination light When patterns, such as the reticle, are projected by projection optics, it aims at enabling it to improve the contrast of the image with the device by the side of illumination-light study equipment.
[Procedure amendment 4]
[Document to be Amended] Specification
[Item(s) to be Amended] 0014
[Method of Amendment] Modification
[Proposed Amendment]
[0014] Moreover, the 2nd illumination-light study equipment is set to the illumination-light study equipment which has the light source (20) which supplies the illumination light, and the condensing optical system (26) which illuminates the predetermined field on a body (12) to homogeneity by this illumination light, as shown in drawing 3. The inclination light means forming (24) which forms the secondary light source which carried out eccentricity to the optical axis of the condensing optical system by the illumination light, and illuminates the predetermined field from across is arranged between the light source (20) and its condensing optical system (26). This inclination light is changed and a polarization means (25B, 25C) to form the illumination light which carries out the linearly polarized light in the direction which intersected perpendicularly to the plane of incidence of the inclination light which carries out oblique illumination of that predetermined field is arranged between that inclination light means forming (24) and its condensing optical system (26). Moreover, the exposure approach by this invention illuminates the reticle as the body using the illumination-light study equipment of this invention, and imprints the pattern of the reticle.
[Procedure amendment 5]
[Document to be Amended] Specification
[Item(s) to be Amended] 0028
[Method of Amendment] Modification
[Proposed Amendment]
[0028]
[Example] Hereafter, with reference to drawing 3 and drawing 4, it explains per 1st example of this invention. This example applies this invention to the illumination-light study system of a projection aligner. The illumination-light study system of the projection aligner of this example is shown, the illumination light from the light source 20 which consists of a mercury lamp is condensed in the ellipse mirror 21 in this drawing 3, and this condensed illumination light carries out incidence of drawing 3 to the fly eye lens 23 (optical integrator) through a collimator lens 22. Field-like the secondary light source is formed in the focal plane by the side of injection of the fly eye lens 23 (reticle side).
[Procedure amendment 6]
[Document to be Amended] Specification
[Item(s) to be Amended] 0043
[Method of Amendment] Modification
[Proposed Amendment]

[0043]
[Effect of the Invention] According to this invention, it inclines to a body, and when the pattern on the body is Rhine - and - tooth-space pattern which make a longitudinal direction a direction perpendicular to the plane of incidence of the illumination light, and the pattern of the body is projected by projection optics, there is [since the illumination light which carries out incidence is polarizing in the direction perpendicular to plane of incidence,] an advantage which can improve the contrast of the image sharply.

[Translation done.]

【特許請求の範囲】

【請求項１】　照明光学系からの照明光によって物体上の所定領域を均一に照明する照明光学装置において、

前記照明光学系は、前記所定領域を斜め方向から照明する傾斜光を形成する傾斜光形成手段と、該傾斜光を変換して、前記所定領域を傾斜照明する前記傾斜光の入射面に対し直交した方向に直線偏光する照明光を形成する偏光手段とを有することを特徴とする照明光学装置。

【請求項２】　照明光を供給する光源と該照明光で物体上の所定領域を均一に照明する集光光学系とを有する照明光学装置において、

前記照明光によって前記集光光学系の光軸に対し偏心した２次光源を形成して前記所定領域を斜め方向から照明する傾斜光形成手段を前記光源と前記集光光学系との間に配置し、

該傾斜光を変換して、前記所定領域を傾斜照明する傾斜光の入射面に対し直交した方向に直線偏光する照明光を形成する偏光手段を前記傾斜光形成手段と前記集光光学系との間に配置したことを特徴とする照明光学装置。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、例えば半導体素子又は液晶表示素子等を製造する際に使用される投影露光装置の照明系に適用して好適な照明光学装置に関する。

【０００２】

【従来の技術】半導体素子又は液晶表示素子等をフォトリソグラフィー技術を用いて製造する際に、フォトマスク又はレチクル（以下、「レチクル」と総称する）のパターンを感光基板上に転写する投影露光装置が使用されている。斯かる投影露光装置においては、半導体素子等の高集積化に伴い、より微細なパターンを高解像度で焼き付けることが要求されている。これを実現する方法として、レチクルのパターン領域の異なる透明部からの光の干渉効果を利用する位相シフトレチクル法が特公昭６２－５０８１１号公報に開示されている。この方法をライン・アンド・スペース像に応用すると基本的に０次回折光がなくなり、±１次回折光のみによる結像となり、同一の開口数の投影光学系でも従来のレチクルの場合よりも微細なライン・アンド・スペース像を高い解像度で焼き付けることができる。

【０００３】また、より解像度を高めるための別のアプローチとして、照明光学系を工夫して、微細なパターンを高い解像度で且つ比較的深い焦点深度で焼き付ける方法が本出願人により提案されている（例えば１９９２年３月応用物理学関係連合講演会予稿集３０－ａ－ＮＡ－３，４参照）。以下ではその方法を「複数傾斜照明法」と呼び、図８を参照してその方法につき説明する。先ず図８（ａ）は複数傾斜照明法を適用した照明光学系における２次光源部等の等価光源部１０を示し、この図８（ａ）において、直交座標系を形成するｘ軸及びｙ軸に対してそれぞれ４５°で交差する軸ｘ′及びこの軸ｘ′とｙ軸に関して対称な軸に沿って４個の小光源１１Ａ～１１Ｄが配置されている。この小光源１１Ａ～１１Ｄの配列は、転写対象とするレチクルのパターンが主にｘ軸に平行な長いエッジ又はｙ軸に平行な長いエッジを有するライン・アンド・スペースパターンの場合に適している。

【０００４】図８（ｂ）はその図８（ａ）の等価光源部１０を光源とする投影露光装置の概略構成を示し、この図８（ｂ）において、等価光源部１０の小光源１１Ａからの照明光の主光線１５Ａが図示省略したコンデンサーレンズ系を介してレチクル１２に光軸ＡＸに対して斜めに照射される。等価光源部１０は投影光学系１３の瞳面（入射瞳面）１０Ａと共役であり、この瞳面には開口絞り１３ａが設けられている。そのレチクル１２からは０次回折光（これも符号１５Ａで表す）及び１次回折光１６Ａが光軸ＡＸに対してほぼ対称に射出され、これら０次回折光１５Ａ及び１次回折光１６Ａは投影光学系１３を経てをほぼ同一の入射角θで感光基板としてのウエハ１４に入射する。この場合、０次回折光１５Ａと１次回折光とが光軸ＡＸ対して対称に瞳の周縁近くを通過するため、投影光学系１３の性能限界までの解像度が得られる。

【０００５】また、従来のように０次回折光がウエハ１４に垂直に入射する方式では、ウエハ１４のデフォーカス量に対する０次回折光の波面収差と他の回折光の波面収差とが大きく異なることから、焦点深度が浅くなっている。これに対して、図８（ｂ）の構成では、０次回折光と１次回折光とが等しい入射角でウエハ１４に入射するため、ウエハ１４が投影光学系１３の焦点位置の前後にあるときの０次回折光と１次回折光との波面収差は相等しく、焦点深度が深くなっている。

【０００６】

【発明が解決しようとする課題】その複数傾斜照明法では、ｘ軸方向又はｙ軸方向のライン・アンド・スペースパターン８であれば有効である。これに対して、図９に示すように、長いエッジがｘ軸又はｙ軸に対して４５°の方向のライン・アンド・スペースパターン９の場合は、１０Ａが投影光学系の瞳であるとすると、図８（ａ）の４つの小光源１１Ａ～１１Ｄのうちの２つの小光源１１Ｂ及び１１Ｄからの回折光は、０次回折光１５Ｂ及び１５Ｄのみが投影レンズの瞳１０Ａを通過し、±１次回折光１６Ｂ及び１６Ｄは瞳１０Ａを通過しないため、ウエハ１４上でパターンを形成することはなく、単にウエハ１４を一様に照明することになる。その結果、ウエハ１４上でのパターンのコントラストが低下することとなる。

【０００７】このことを簡単な数値計算で示す。０次回折光の強さに対する±１次回折光の強さをａとし、各小光源１１Ａ～１１Ｄは点光源とみなす。このとき、ｙ軸

方向に長いライン・アンド・スペースパターンの場合のｘ軸上の像強度分布Ｉ（ｘ）は各小光源による像強度分布の和として次のようになる。

【数１】

$$I(x)=4\{1+a^2+2a\cdot\cos[(4\pi/\lambda)(\sin\theta)x]\}$$

【０００８】ここで、入射角θは、図８（ｂ）に示すように、０次回折光又は±１次回折光が光軸ＡＸとなす角である。これに対して、ｘ軸又はｙ軸に４５°で交差する方向に長いライン・アンド・スペースパターンの場合に、４５°方向の座標軸をｘ′軸とすると、強度分布Ｉ（ｘ′）は次のようになる。

【数２】

$$\begin{aligned}I(x')&=2\{1+a^2+2a\cdot\cos[(4\pi/\lambda)(\sin\theta)x]\}\\&\quad+2\{1\}\\&=4\{1+(a^2/2)+a\cdot\cos[(4\pi/\lambda)(\sin\theta)x]\}\end{aligned}$$

【０００９】（数１）及び（数２）から各々の強度分布のコントラストＣｘ及びＣｘ′を求めると、次のようになる。

【数３】

$$Cx=2a/(1+a^2),\ Cx'=a/(1+a^2/2)$$

【００１０】この場合、次式が成立する。

$$Cx-Cx'=a/\{(1+a^2)(1+a^2/2)\}>0$$

従って、次式が成立する。

【数４】$Cx>Cx'$

【００１１】従って、ｘ軸に４５°で交差する方向に長いパターンのコントラストの低下が示される。例えばラインとスペースとの幅が等しい場合には、±１次回折光の強さａは２／πとなるので、次式のようになる。

$Cx=0.906,\ Cx'=0.529$

【００１２】なお、上述の説明では複数傾斜照明法の場合を例として説明したが、例えば輪帯照明法等を使用した場合でも、像のコントラストをより改善することが望まれている。本発明は斯かる点に鑑み、光軸に対して傾斜した照明光を積極的に利用してレチクル等を照明する照明光学装置において、そのレチクル等のパターンがその照明光の入射面に垂直な方向を長手方向とするライン・アンド・スペースパターンであるような場合に、投影光学系でそのレチクル等のパターンを投影したときに照明光学装置側の工夫でその像のコントラストを改善できるようにすることを目的とする。

【００１３】

【課題を解決するための手段】本発明による第１の照明光学装置は、例えば図３に示すように、照明光学系からの照明光によって物体（１２）上の所定領域を均一に照明する照明光学装置において、その照明光学系は、その所定領域を斜め方向から照明する傾斜光（２７Ｂ，２７Ｃ）を形成する傾斜光形成手段（２４）と、この傾斜光を変換して、その所定領域を傾斜照明するその傾斜光の入射面に対し直交した方向に直線偏光する照明光を形成する偏光手段（２５Ｂ，２５Ｃ）とを有するものである。

【００１４】また、第２の照明光学装置は、例えば図３に示すように、照明光を供給する光源（２０）とこの照明光で物体（１２）上の所定領域を均一に照明する集光光学系（２６）とを有する照明光学装置において、その照明光によってその集光光学系の光軸に対し偏心した２次光源を形成してその所定領域を斜め方向から照明する傾斜光形成手段（２４）をその光源（２０）とその集光光学系（２６）との間に配置し、この傾斜光を変換して、その所定領域を傾斜照明する傾斜光の入射面に対し直交した方向に直線偏光する照明光を形成する偏光手段（２５Ｂ，２５Ｃ）をその傾斜光形成手段（２４）とその集光光学系（２６）との間に配置したものである。

【００１５】

【作用】以下、本発明の原理につき偏心した４個の小光源からの照明光で物体を照明する複数傾斜照明法を例にとって説明する。先ず、本発明の第１の照明光学装置によれば、例えば図３に示すように、物体（１２）の所定領域を斜め方向から照明する傾斜光（２７Ｂ，２７Ｃ）が形成され、これら傾斜光（２７Ｂ，２７Ｃ）はそれぞれ物体（１２）に対する入射面（紙面）に垂直な方向に直線偏光（入射面に垂直な方向に電気ベクトルが振動）している。なお、直線偏光とは、光波の電気ベクトルの振動方向が一平面内にある状態を意味し、電気ベクトルの振動方向を直線偏光の方向と定義する。また、入射面とは、光が媒質の境界面に達した時に、その点での面の法線と光の入射方向とを含む面の事と定義する。その図３の照明光学装置を簡略化すると図１のようになる。

【００１６】図１（ａ）は図３の照明光学装置の２次光源部等の等価光源部１０を示し、この図１（ａ）において、直交座標系を形成するｘ軸及びｙ軸に対してそれぞれ４５°で交差する軸ｘ′及びこの軸ｘ′とｙ軸に関して対称な軸に沿って４個の小光源１１Ａ～１１Ｄが配置されている。

【００１７】図１（ｂ）はその図３の照明光学装置を用いた投影露光装置の概略構成を示し、この図１（ｂ）において、等価光源部１０は図１（ａ）の等価光源部と等しい。その等価光源部１０の小光源１１Ａからの露光光の主光線１５Ａが図示省略したコンデンサーレンズ系を介してレチクル１２に光軸ＡＸに対して斜めに照射される。その主光線１５Ａが図３の傾斜光（２７Ｂ，２７Ｃ）に対応する。その主光線１５Ａの入射面は図１

（ｂ）の紙面に平行であるため、本発明によれば、その主光線１５Ａは図１（ｂ）の紙面に垂直な方向に直線偏光（紙面に垂直な方向に電気ベクトルが振動）してレチクル１２に入射する。同様に、図１（ａ）において、各小光源１１Ｂ～１１Ｄからの光は、図１（ａ）の矢印の方向即ち、レチクル１２に対する入射面に垂直な方向に直線偏光して図１（ｂ）のレチクル１２に入射する。

【００１８】また、レチクル１２からの０次回折光（これをも符号１５Ａで表す）及び１次回折光１６Ａは投影光学系１３を経てウエハ１４上に入射する。先ず、そのレチクル１２に形成されたパターンが、従来例に好適なパターンである図１（ａ）のｘ軸又はｙ軸に平行な方向に長いライン・アンド・スペースパターンであるとすると、そのパターンによりｘ方向又はｙ方向に回折された照明光は、偏光方向がそのパターンに対して４５°方向であるので、ランダム偏光と同じ結像状況である。従って、コントラストは従来例と同様である。

【００１９】これに対して、そのレチクル１２に形成されたパターンが、図１（ａ）のｘ’軸に垂直な方向に長いライン・アンド・スペースパターン９であるとすると、小光源１１Ａからの照明光１５Ａの１次回折光が投影光学系１３の瞳内に入ることになる。尚、図１（ｂ）ではｘ’軸は紙面と平行になっている。ここで、図１（ｂ）に示すように、その照明光１５Ａの０次回折光１５Ａ及び１次回折光１５Ｂは共に偏光方向（電気ベクトルの振動する方向）がウエハ１４の表面で平行なＳ偏光（図１（ｂ）の紙面に垂直な方向に電気ベクトルが振動する光）である。従って、ウエハ１４上における干渉効果がランダム偏光のときよりも大きくなり、高コントラストの像が作られる。このため、図９を用いて説明したようにｘ’方向に回折された場合に、回折光の一部が瞳外に出てしまうことによりコントラストが低下するという従来の不都合が補われることになる。

【００２０】ここで、偏光方向による強度分布の差を簡単に以下に述べる。図２では、像面、即ちウエハ１４の表面付近の様子をＰ偏光（電気ベクトルの振動方向が入射面内にある光）とＳ偏光（電気ベクトルの振動方向が入射面と垂直な光）を用いて示してある。０次回折光１５Ａ及び１次回折光１６Ａの入射角をそれぞれθ_0及びθ_1とすると、Ｓ偏光の場合の像面上の強度分布Ｉｓ（ｘ）は振幅分布Ｕｓ（ｘ）を用いて次のように簡単に示される。

【数５】

$$I_s(x)=|U_s(x)|^2,$$
$$V_s(x)=a_0\cdot\exp[-i(2\pi/\lambda)(\sin\theta_0)x]+a_1\cdot\exp[-i(2\pi/\lambda)(\sin\theta_1)x]$$

【００２１】従って、強度分布Ｉｓ（ｘ）は次のようになる。

【数６】

$$I_s(x)=a_0^2+a_1^2+2a_0a_1\cdot\cos[(2\pi/\lambda)(\sin\theta_0-\sin\theta_1)x]$$

ここで、係数a_0及びa_1はそれぞれ０次回折光及び１次回折光の強さ（振幅）である。ｘ’方向にピッチを持つライン・アンド・スペースパターンの場合、４つの小光源の内、２つは０次回折光しか投影光学系１３を通過しないのでＳ偏光のコントラストＣｓは次のようになる。

【数７】$C_s=2a_0a_1/(2a_0^2+a_1^2)$

【００２２】一方、Ｐ偏光の場合は、偏光のｘ成分と、ｚ成分とを考えなくてはいけない。Ｐ偏光の場合の像面上の振幅分布Ｕｐ（ｘ）をベクトルで表して、ｘ成分とｚ成分とを示すと次式が得られる。

【数８】

$$U_p(x)=(a_0\cdot\exp[-i(2\pi/\lambda)(\sin\theta_0)x]\cdot\cos\theta_0+a_1\cdot\exp[-i(2\pi/\lambda)(\sin\theta_1)x]\cdot\cos\theta_1,\ a_0\cdot\exp[-i(2\pi/\lambda)(\sin\theta_0)x]\cdot\sin\theta_0+a_1\cdot\exp[-i(2\pi/\lambda)(\sin\theta_1)x]\cdot\sin\theta_1)$$

【００２３】従って、Ｐ偏光の場合の像面上の強度分布Ｉｐ（ｘ）は次のようになる。

【数９】

$$I_p(x)=|U_p(x)|^2=a_0^2+a_1^2+2a_0a_1\times(\cos\theta_0\cos\theta_1+\sin\theta_0\sin\theta_1)\times\cos[(2\pi/\lambda)(\sin\theta_0-\sin\theta_1)x]$$

【００２４】従って、Ｐ偏光の場合のコントラストＣｐは次のようになる。

【数１０】

$$C_p=2a_0a_1\cos(\theta_0-\theta_1)/(2a_0^2+a_1^2)$$

（数７）と（数１０）とを比較して、Ｐ偏光の場合は、コントラストが$\cos(\theta_0-\theta_1)$倍となることが分かる。例えば、$\sin\theta_0=0.4$、$\sin\theta_1=-0.4$の場合を考えると、$\cos(\theta_0-\theta_1)=0.$

６８となり、Ｐ偏光の場合とＳ偏光の場合とでは大きな差がつく。ランダム偏光は、Ｐ偏光とＳ偏光との平均と考えられるので、コントラストは（１／２）（１＋０．６８）＝０．８４である。

【００２５】このように、Ｓ偏光とすることにより、コントラストに大きな差が生じる。即ち、図１（ａ）のような偏光状態の照明光を使用すると、ｘ軸及びｙ軸に対して４５°で交差する方向にエッジが平行なライン・アンド・スペースパターンに対して、従来よりも２割程度のコントラストの増加が見込まれ、微細パターンに有効であることが分かる。

【００２６】なお、これまでは複数傾斜照明法を例にとって説明したが、本発明を例えば輪帯照明法に適用すると、例えば図７（ａ）に示すように、等価光源部１０の輪帯状の光源からの光をそれぞれ入射面に垂直な方向、即ち光軸を中心とした円の接線方向に直線偏光する光に変換すればよい。

【００２７】次に、本発明の第２の照明光学装置によれば、例えば図３に示すように、傾斜光を形成するのに、光源からの照明光により偏心した２次光源が形成されている。その２次光源を例えば図１（ａ）の等価光源１０とみなせば、上述の説明はそのまま本発明にも適用される。

【００２８】

【実施例】以下、本発明による照明光学装置を備えた投影露光装置の第１実施例につき図３及び図４を参照して説明する。本例は投影露光装置の照明光学系に本発明を適用したものである。図３は本実施例の投影露光装置の照明光学系を示し、この図３において、水銀ランプよりなる光源２０からの照明光が楕円鏡２１で集光され、この集光された照明光がコリメータレンズ２２を介してフライアイレンズ２３（オプティカルインテグレータ）に入射する。フライアイレンズ２３の射出側（レチクル側）の焦点面には面状の２次光源が形成される。

【００２９】フライアイレンズ２３の射出端付近に光軸ＡＸに対して偏心した４個の開口が形成された空間フィルター２４を設ける。また、この空間フィルター２４の４個の開口のレチクル側（又は光源２０側でもよい）にそれぞれ偏光板２５Ａ～２５Ｄを被着する。但し、図３では偏光板２５Ｂ及び２５Ｃのみが現れている。図４（ａ）は図３の空間フィルター２４をレチクル側から見た正面図、図４（ｂ）は図４（ａ）のＡＡ線に沿う断面図であり、これら図４（ａ）及び（ｂ）に示すように、空間フィルター２４には光軸ＡＸを中心として、９０°間隔で４個の開口２４ａ～２４ｄが形成され、これら開口がそれぞれ偏光板２５Ａ～２５Ｄで覆われている。また、それら偏光板２５Ａ～２５Ｄの偏光方向はそれぞれ矢印で示すように、光軸ＡＸを中心とした円周の接線方向に設定されている。従って、その空間フィルター２４の開口２４ａ～２４ｄから射出される照明光は、それぞれ光軸ＡＸを中心とした円周の接線方向にほぼ平行な方向に直線偏光している。

【００３０】図３に戻り、空間フィルター２４により光軸ＡＸに対して偏心した４個の２次光源が形成される。それら４個の２次光源から射出された照明光はそれぞれ偏光板２５Ａ～２５Ｄを通過した後に、コンデンサーレンズ系２６を経てレチクル１２に入射する。尚、コンデンサーレンズ系２６の前側焦点（光源側焦点）位置には、空間フィルター２４（偏光板２５Ａ～２５Ｄ）が設けられており、レチクル１２のパターン形成面はコンデンサーレンズ系２６に関して空間フィルター２４の配置面とフーリエ変換の関係にある。この場合、例えば空間フィルター２４の開口２４ｂ及び２４ｃから射出された主光線２７Ｂ及び２７Ｃはコンデンサーレンズ系２６を経てそれぞれレチクル１２上に光軸ＡＸに対して斜めに入射する。また、これら主光線２７Ｂ及び２７Ｃはそれぞれレチクル１２に対する入射面（紙面方向）に対して垂直な方向に直線偏光している。

【００３１】このような照明光学系を使用すると、本発明の原理説明で説明したように、例えばレチクル１２上に図４（ａ）の開口２４ａと２４ｃとを結ぶ直線に対して平行又は垂直な方向に長いエッジを有するライン・アンド・スペースパターンが形成されている場合に、従来よりも良好なコントラストのもとでそのパターンを投影光学系１３を通してウエハ１４上に投影することができる。ここで、図３の装置では、フライアイレンズ２３の入射側面と物体面（レチクル１２又はウエハ１４）とが共役に構成されており、フライアイレンズ２３の射出側面（２次光源１０）と投影光学系１３の瞳面１０Ａとが共役に構成されている。なお、図３の構成の他に、フライアイレンズ２３と空間フィルター２４との間に別の大きな偏光板を配置し、空間フィルター２４の４個の開口２４ａ～２４ｄの一部又は全部に１／２波長板を配置して、各１／２波長板の回転角を調整するようにしてもよい。これによっても、図４（ａ）に示すような、光軸ＡＸを中心とする円周の接線方向に偏光した照明光が得られる。この場合、別の大きな偏光板の偏光方向によつては、１／２波長板は空間フィルター２４のすべての開口に設ける必要はない。

【００３２】更に、例えば光源として直線偏光のレーザービームが射出されるようなレーザー光源を使用することにより、等価光源となる図３の空間フィルター２４の全体を直線偏光の照明光で照明する場合には、空間フィルター２４の４個の開口２４ａ～２４ｄの一部または全部に適当な回転方向の１／２波長板を設けるだけでよい。この場合、一部の開口に１／２波長板を設けるだけでもよいが、全部の開口に１／２波長板を設けるほうが照明のバラツキを低減する上で効果がある。このように１／２波長板を使用して偏光方向を調整した場合には、照明光の損失がないので照明効率が良い。

【0033】また、全体として円偏光の照明光を発生する装置を用いて、等価光源となる図3の空間フィルター24を照明する場合には、空間フィルター24の各開口に適当な回転方向の1／4波長板を設けることがよい。

【0034】次に、本発明の第2実施例につき図5を参照して説明する。図5は本例の投影露光装置を示し、この図5において、光源20からの照明光は楕円鏡21、折り曲げミラー28及びインプットレンズ29を経てほぼ平行光束になる。その楕円鏡21と折り曲げミラー28との間にシャッター30を配置し、このシャッター30を駆動モーター31で閉じることにより、インプットレンズ29に対する照明光の供給を随時停止する。光源1としては、水銀ランプの外に、例えばＫｒＦレーザー光等を発生するエキシマレーザー光源等を使用することができる。エキシマレーザー光源を使用する場合には、楕円鏡21～インプットレンズ29までの光学系の代わりにビームエクスパンダ等が使用される。

【0035】そして、インプットレンズ29から順に、4角錐型（ピラミッド型）の凹部を有する第1の多面体プリズム32及び4角錐型（ピラミッド型）の凸部を有する第2の多面体プリズム33を配置する。この第2の多面体プリズム33から射出される照明光は、光軸を中心として光軸の周囲に等角度で4個の光束に分割されている。

【0036】これら4個に分割された光束をそれぞれ第2群のフライアイレンズ34Ａ，34Ｂ，34Ｃ及び34Ｄに入射させる。図5ではフライアイレンズ34Ａ及び34Ｂのみが示されているが、図5の紙面に垂直な方向に光軸を挟んで2個のフライアイレンズ34Ｃ及び34Ｄが配置されている。そして、フライアイレンズ34Ａから射出された光束は、レンズ系35Ａ及び36Ａよりなるガイド光学系を介してほぼ平行光束に変換されて第1群のフライアイレンズ37Ａに入射する。同様に、第2群のフライアイレンズ34Ｂを射出した光束は、レンズ系35Ｂ及び36Ｂよりなるガイド光学系を介してほぼ平行光束に変換されて第1群のフライアイレンズ37Ｂに入射し、図示省略するも、第2群のフライアイレンズ34Ｃ及び34Ｄを射出した光束は、それぞれガイド光学系を介して第1群のフライアイレンズ37Ｃ及び37Ｄに入射する。

【0037】第1群のフライアイレンズ37Ａ～37Ｄは光軸の回りに90°間隔で配置されている。第1群のフライアイレンズ37Ａ～37Ｄのレチクル側焦点面にはそれぞれ面状の2次光源が形成されるが、それら2次光源の形成面にそれぞれ可変開口絞り38Ａ～38Ｄを配置する。更に、これら可変開口絞り38Ａ～38Ｄのレチクル側にそれぞれ偏光板39Ａ～39Ｄを配置する。なお、図5では可変開口絞り13Ａ，13Ｂ及び偏光板39Ａ，39Ｂのみが現れている。

【0038】それら可変開口絞り38Ａ～38Ｄから偏光板39Ａ～39Ｄを透過して射出した照明光は、それぞれ補助コンデンサーレンズ40、ミラー41及び主コンデンサーレンズ42を経て適度に集光されてレチクル12をほぼ均一な照度で照明する。そのレチクル12のパターンが投影光学系13によりウエハステージWS上のウエハ14に所定の縮小倍率βで転写される。それら偏光板39Ａ～39Ｄの偏光方向は、光軸ＡＸを中心とする円周の接線方向に平行である。例えば可変開口絞り38Ａから偏光板39Ａを透過して射出される光束の主光線43Ａは、紙面に垂直な方向に直線偏光した状態でレチクル12上に光軸ＡＸに対して斜めに入射する。なお、図5に示した偏光板39Ａ～39Ｄは、実質的に、補助コンデンサーレンズ40と主コンデンサーレンズとの合成系のコンデンサーレンズ系の前側焦点（光源側焦点）位置に設けられており、この位置は実質的に投影光学系13の瞳面10Ａと共役である。

【0039】本例によっても、レチクル12上の所定の方向のライン・アンド・スペースパターンのウエハ14上の投影像のコントラストを改善することができる。更に、第1群のフライアイレンズ37Ａ～37Ｄの他に第2群のフライアイレンズ34Ａ～34Ｄが設けられているので、レチクル12上の照度の均一性が更に改善されている。なお、図5において、偏光板39Ａ及び39Ｂはそれぞれ例えばリレー光学系の間の位置44Ａ及び44Ｂに配置してもよく、更に他の位置に配置してもよい。また、光源20からの照明光が既に直線偏光であるような場合には、偏光板39Ａ及び39Ｂの代わりに1／2波長板を使用してもよい。

【0040】次に、本発明の第3実施例につき図6及び図7を参照して説明する。本実施例は、先に説明した図3に示す第1実施例の空間フィルター24を変えて、図6（ａ）に示す如き輪帯状の開口240ａを有する空間フィルター240をフライアイレンズ23の射出側に設けた例を示すものである。この空間フィルター240の配置により、フライアイレンズ23の射出側には、図6（ａ）に示す如く、光軸ＡＸから偏心した輪帯状の2次光源45が形成され、この輪帯状の2次光源45からの光が、図3に示す如く、コンデンサーレンズ26、レチクル12を介して投影光学系13の瞳面10Ａ（入射瞳面）に達する。ここで、説明を簡単にするために、レチクル12のライン・アンド・スペースパターンの回折作用による0次回折光と1次回折光との様子について考えると、この投影光学系13の瞳面10Ａには、図6（ｂ）に示す如く、輪帯光源45と相似な輪帯状の0次回折光45Ａと輪帯状の0次回折光45Ａを横ずれさせた輪帯状の1次回折光45Ｂが形成される。

【0041】この場合、本例では図7（ａ）に示すように、等価光源部10の輪帯状の2次光源45から射出される照明光をそれぞれ光軸ＡＸを中心とする円周の接線方向に偏光させる輪帯状の偏光板250が空間フィルタ

－２４０上に設けられている。これにより、微細パターンに対して高コントラストの像を得ることができる。なお、図７（ｂ）に示すように輪帯状光源を円弧状の各ゾーンに分ける開口を持つ空間フィルター２４０を用いて、各ゾーン上に偏光板２５０Ａ～２５０Ｈを設けて、各ゾーンごとに光軸ＡＸを軸とする円周の接線方向の直線偏光の照明光となるようにしてもよい。

【００４２】なお、本発明は上述実施例に限定されず本発明の要旨を逸脱しない範囲で種々の構成を取り得ることは勿論である。

【００４３】

【発明の効果】本発明の第１及び第２の照明光学装置によれば、物体に対して傾斜して入射する照明光が入射面に垂直な方向に偏光しているので、その物体上のパターンがその照明光の入射面に垂直な方向を長手方向とするライン・アンド・スペースパターンであるような場合に、投影光学系でその物体のパターンを投影したときにその像のコントラストを大幅に改善できる利点がある。

【図面の簡単な説明】

【図１】（ａ）は本発明による照明光学装置の原理の説明に供する等価光源を示す図、（ｂ）は図１（ａ）の等価光源を使用した投影露光装置を示す概略構成図である。

【図２】本発明の原理の説明に供する図である。

【図３】本発明の第１実施例の投影露光装置の照明光学系を示す構成図である。

【図４】（ａ）は図３の空間フィルター２４及び偏光板２５Ａ～２５Ｄを示す正面図、（ｂ）は図４（ａ）のＡ線に沿う断面図である。

【図５】本発明の第２実施例の投影露光装置を示す構成図である。

【図６】（ａ）は本発明の第３実施例の等価光源及び空間フィルター２４０を示す図、（ｂ）は空間フィルター２４０を用いた事による投影光学系１３の瞳での回折光の様子を示す図である。

【図７】（ａ）は第３実施例の等価光源からの照明光の偏光状態を示す図、（ｂ）は第３実施例の変形例の等価光源を示す図である。

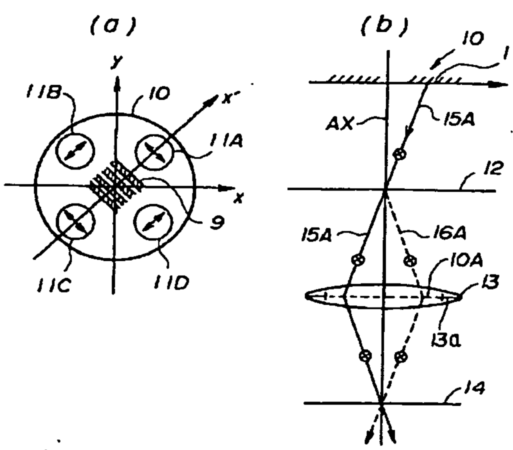
【図８】（ａ）は複数傾斜照明の等価光源を示す図、（ｂ）は図８（ａ）の等価光源を用いた場合の投影光学系１３の瞳での回折光の様子を示す図である。

【図９】複数傾斜照明で特定のパターンを照明した場合を示す図である。

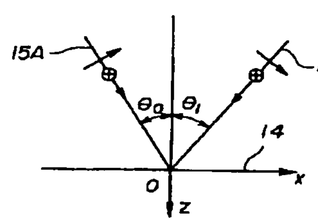
【符号の説明】

１０　等価光源
１１Ａ～１１Ｄ　小光源
１２　レチクル
１３　投影光学系
１４　ウエハ
２０　光源
２２　コリメータレンズ
２３　フライアイレンズ
２４　空間フィルター
２４ａ～２４ｄ　開口
２５Ａ～２５Ｄ　偏光板
２６　コンデンサーレンズ系

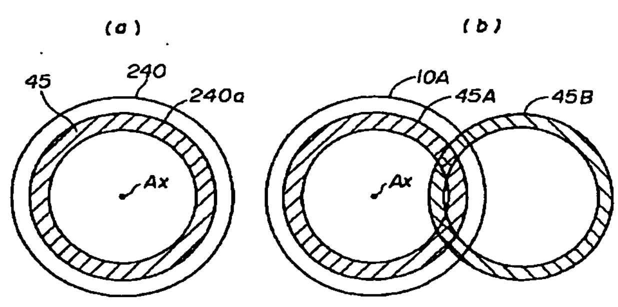
【図１】



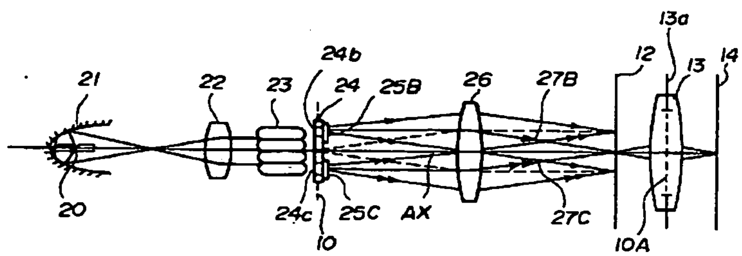
【図２】



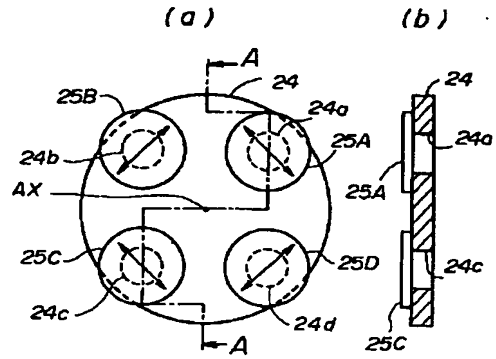
【図６】



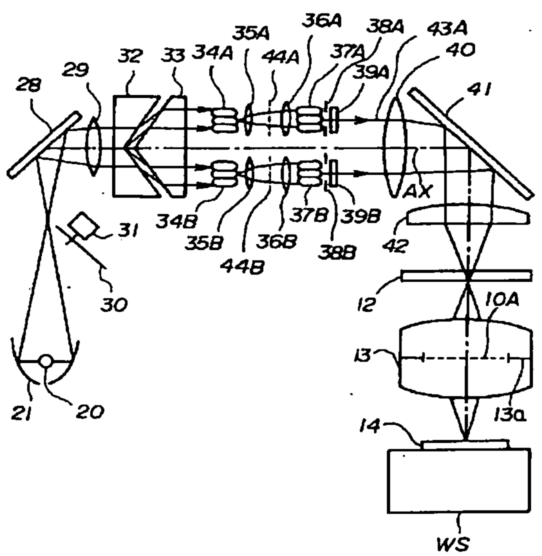
【図３】



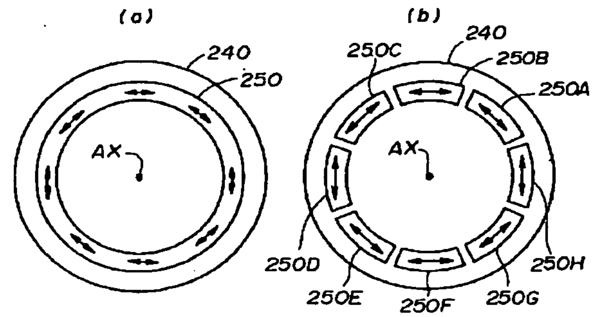
【図４】



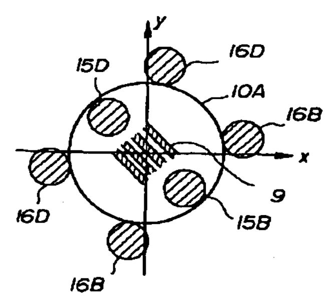
【図５】



【図７】



【図９】



【図８】